Interactive Metaprogramming Shell Based on Clang

Ábel Sinkovics, András Kucsma

Agenda

- What is template metaprogramming?
- Where is TMP used?
- How TMP works?
- How to do TMP with Metashell?
- Demos

Template metaprogramming

What is template metaprogramming?

Template metaprogramming

- ”Disaster” Alex Ispánovics
- ”Executing compile-time algorithms with the help of cleverly defined templates” Zoli<1>
- ”It is not something people can not deal with, it is something compilers can not deal with” Tibi
- ”Unwaitable compile-time and infinite memory needs” Dani
- ”Intellectual entertainment” Zoli<2>

Template metaprogramming

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He is a professor!!!

min

```
int main()
{
  std::cout << min(2,  3 ) << std::endl;
}
```

min

```
int main()
{
  std::cout << min(2,  3 ) << std::endl;
}
```

```
template <    class T     >
                T                   min(T a, T b)
{
  return a < b ? a : b;
}
```

min

```
int main()
{
  std::cout << min(2, 3.4) << std::endl;
}
```

```
template <    class T     >
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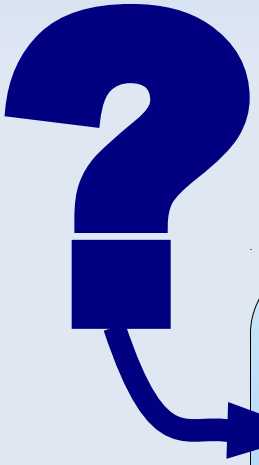

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min

```
int main()
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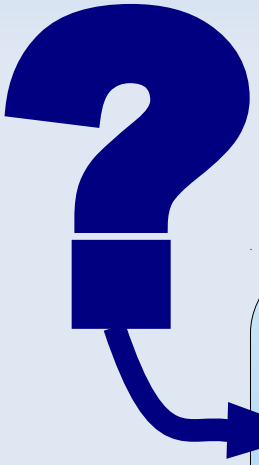
}
```

```
template <class A, class B>
struct common_type
{
  typedef /* ... */ type;
}
```



```
template <class A, class B>
                                    min(A a, B b)
{
  return a < b ? a : b;
}
```

min

```
int main()
{
  std::cout << min(2, 3.4) <<
}
```

```
template <class A, class B>
struct common_type
{
  typedef /* ... */ type;
}
```

```
template <class A, class B>
typename common_type<A, B>::type min(A a, B b)
{
  return a < b ? a : b; // ...
}
```

min

```
template <class A, class B>
struct common_type;
```

min

```
template <class A, class B>
struct common_type;

template <>
struct common_type<int, double>
{
  typedef double type;
};
```

min

```
template <class A, class B>
struct common_type;

template <>
struct common_type<int, double>
{
  typedef double type;
};

// ...
```

min

```
template <class A, class B>
struct common_type;

template <>
struct common_type<int, double>
{
  typedef double type;
};

// ...

template <class T>
struct common_type<T, T>
{
  typedef T type;
};
```

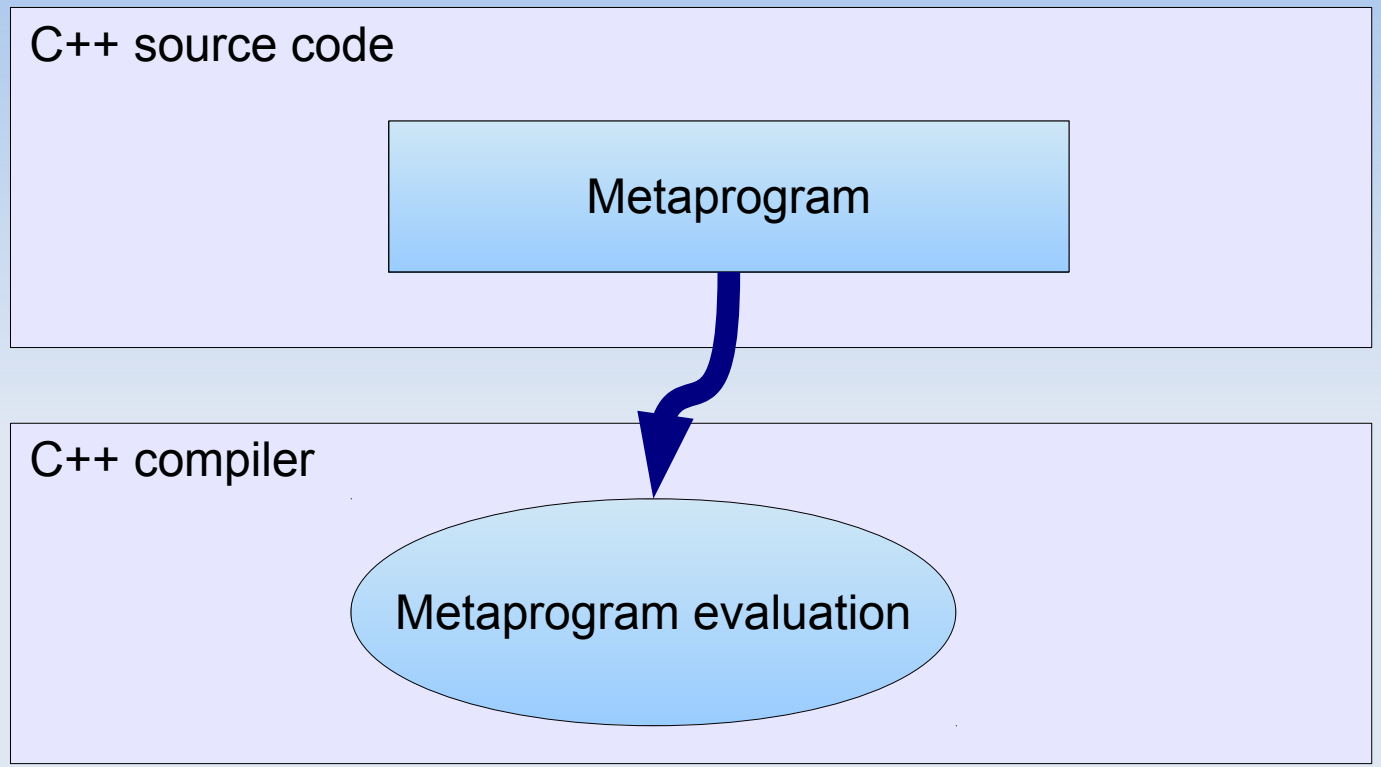
min

```
template <class A, class B>
struct common_type
{
  using type =
   decltype(true ? std::declval<A>() : std::declval<B>());
};
```

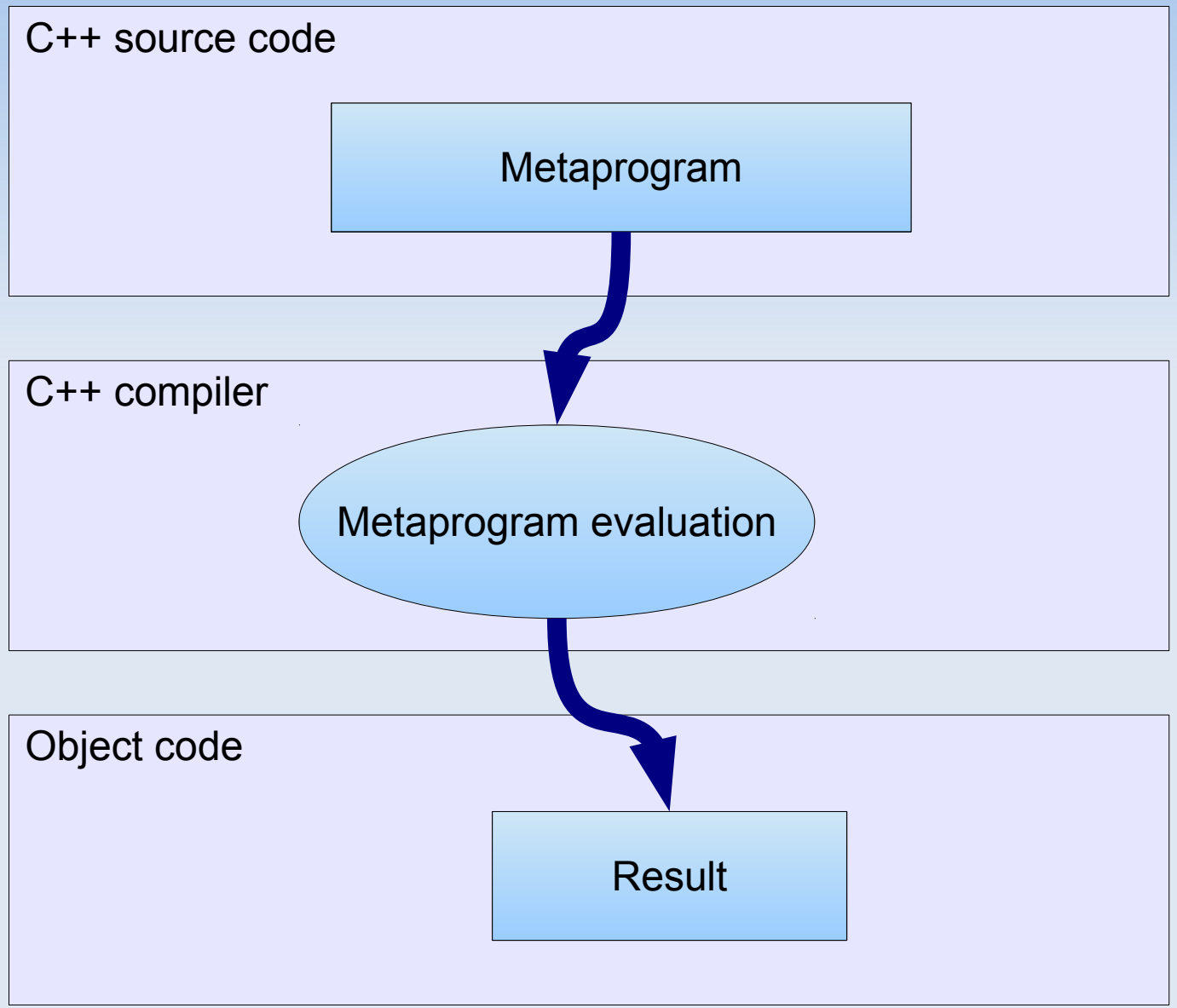
```
template <class... Ts>
struct common_type
{
  // ...
};
```

Metaprogramming in C++

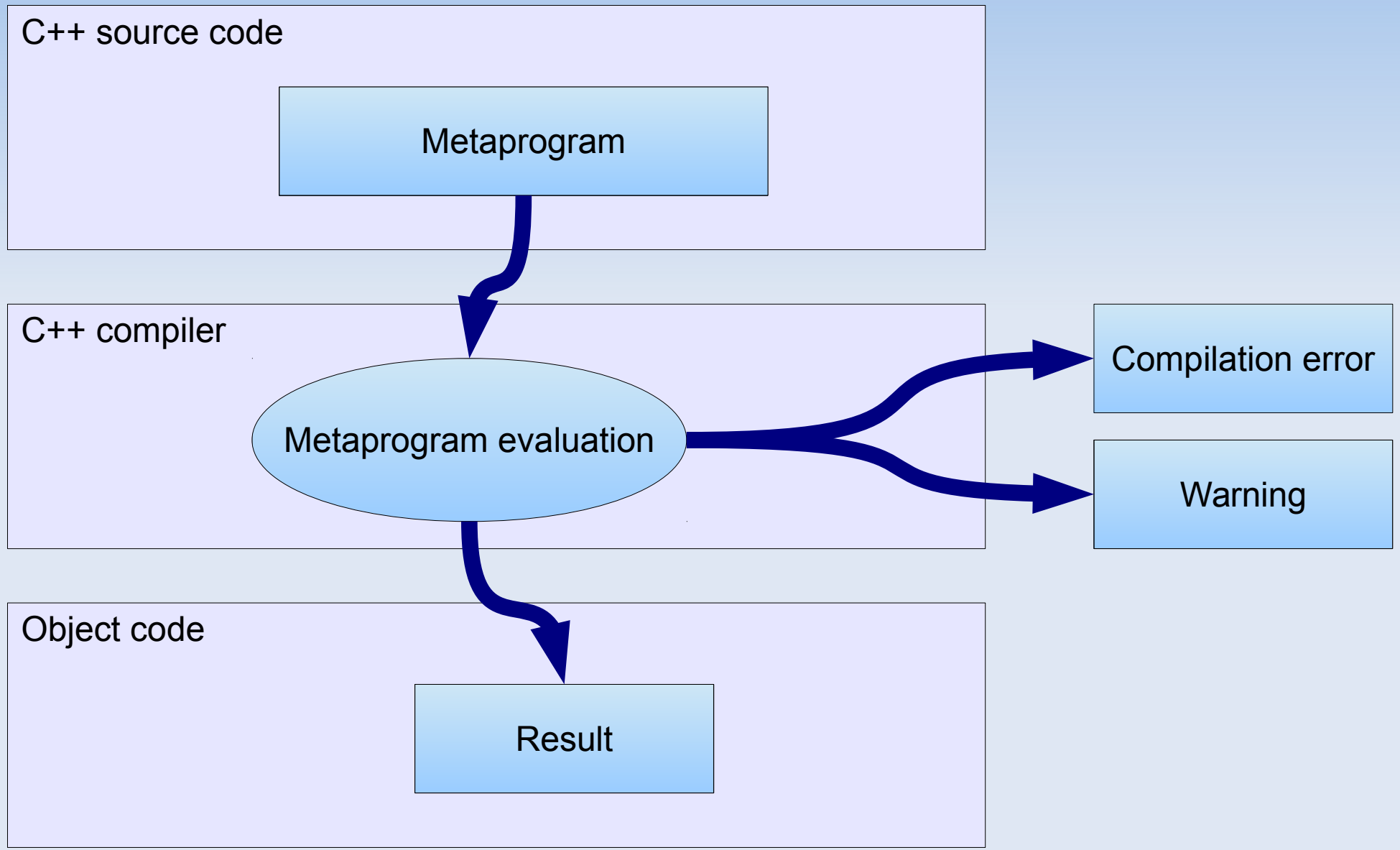
Metaprogramming in C++



Metaprogramming in C++



Metaprogramming in C++



Application areas

- Type calculations in generic code
- Simulating/experimenting with language features
- Extra ”optimisations”
- Validation
- Domain specific language embedding

Lambda expressions

- Lambda expressions in C++98 (Boost.Phoenix)

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- Display the values grater than 5

```
std::vector<int> v;
```

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```
std::vector<int> v;
std::for_each(v.begin(), v.end(),



);
```

Lambda expressions

- Lambda expressions in C++98 (Boost.Phoenix)
- Display the values grater than 5

```
std::vector<int> v;
std::for_each(v.begin(), v.end(),
  if_(         )


);
```

Lambda expressions

- Lambda expressions in C++98 (Boost.Phoenix)
- Display the values grater than 5

```
std::vector<int> v;
std::for_each(v.begin(), v.end(),
  if_(arg1 > 5)


);
```

Lambda expressions

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std::vector<int> v;
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  ]
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Lambda expressions

- Lambda expressions in C++98 (Boost.Phoenix)
- Display the values grater than 5

```
std::vector<int> v;
std::for_each(v.begin(), v.end(),
  if_(arg1 > 5) [
    std::cout << arg1 << ", "
  ]
);
```

Expression templates

- Todd Veldhuizen
- Do ”optimisation”s at compile-time
- Extra ”optimisation”s based on domain knowledge
  - The compiler is not aware of them

Parsing at compile time

- Take a string literal and turn it into a C++ construct (value, object, function, template metaprogram, etc.)

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- Examples:
  - `checked_query("select LOCATION from EMPLOYEE join DEPARTMENT where DIVNUM = 2")`
  - `checked_regex("x[ab]")`
  - `RULE("S ::= DOUBLE (',' DOUBLE)*")`

Parsing at compile time

- Take a string literal and turn it into a C++ construct (value, object, function, template metaprogram, etc.)
- Examples:
  - `checked_query("select LOCATION from EMPLOYEE join DEPARTMENT where DIVNUM = 2")`
  - `checked_regex("x[ab]")`
  - `RULE("S ::= DOUBLE (',' DOUBLE)*")`
- Constexpr-based solution: Sprout
- TMP-based solution: Mpllibs.Metaparse

C++ template metaprogramming

```
template <int N>
struct fact
{


};
```

C++ template metaprogramming

```
template <int N>
struct fact
{
  static const int value =

};
```

C++ template metaprogramming

```
template <int N>
struct fact
{
  static const int value =
    N * fact<N – 1>::value;
};
```

C++ template metaprogramming

```
template <int N>
struct fact
{
  static const int value =
    N * fact<N – 1>::value;
};

template <>
struct fact<0>
{
  static const int value =
    1;
};
```

C++ template metaprogramming

```
fact<3>::value
```

```
template <int N>
struct fact
{
  static const int value =
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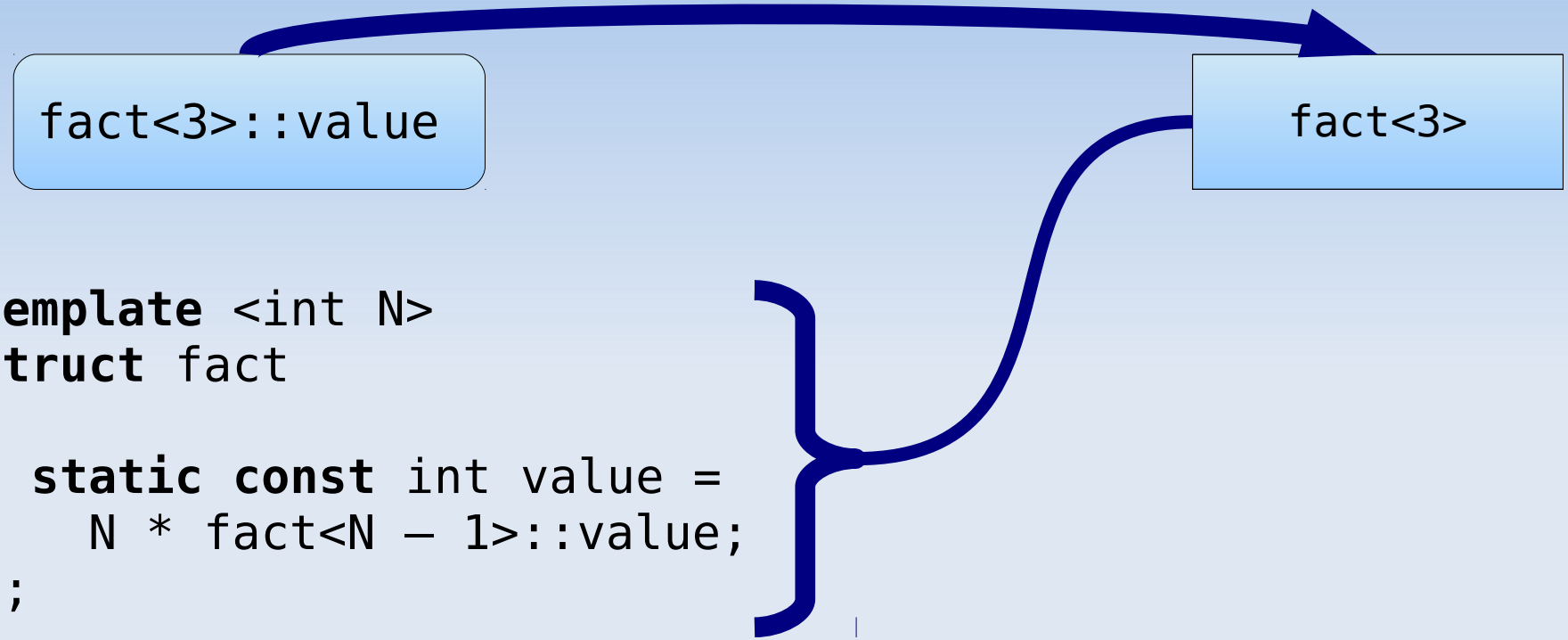
C++ template metaprogramming

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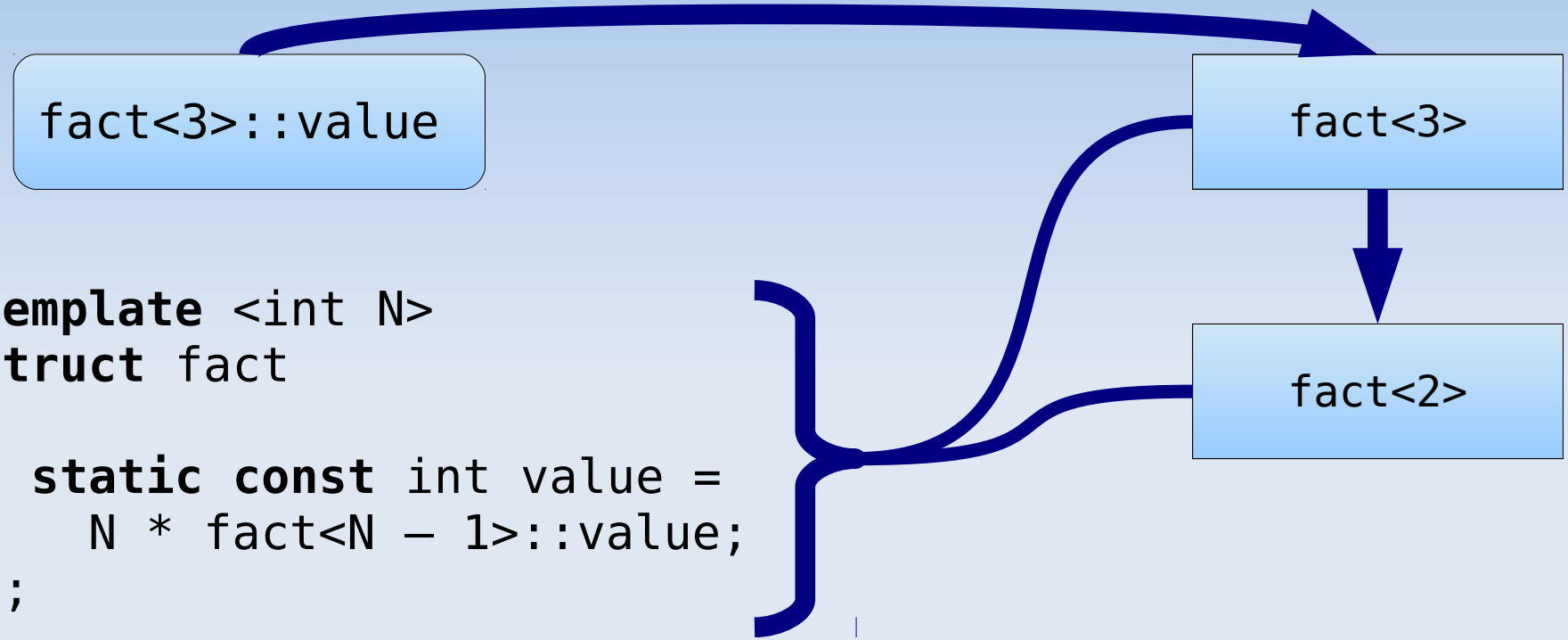
C++ template metaprogramming

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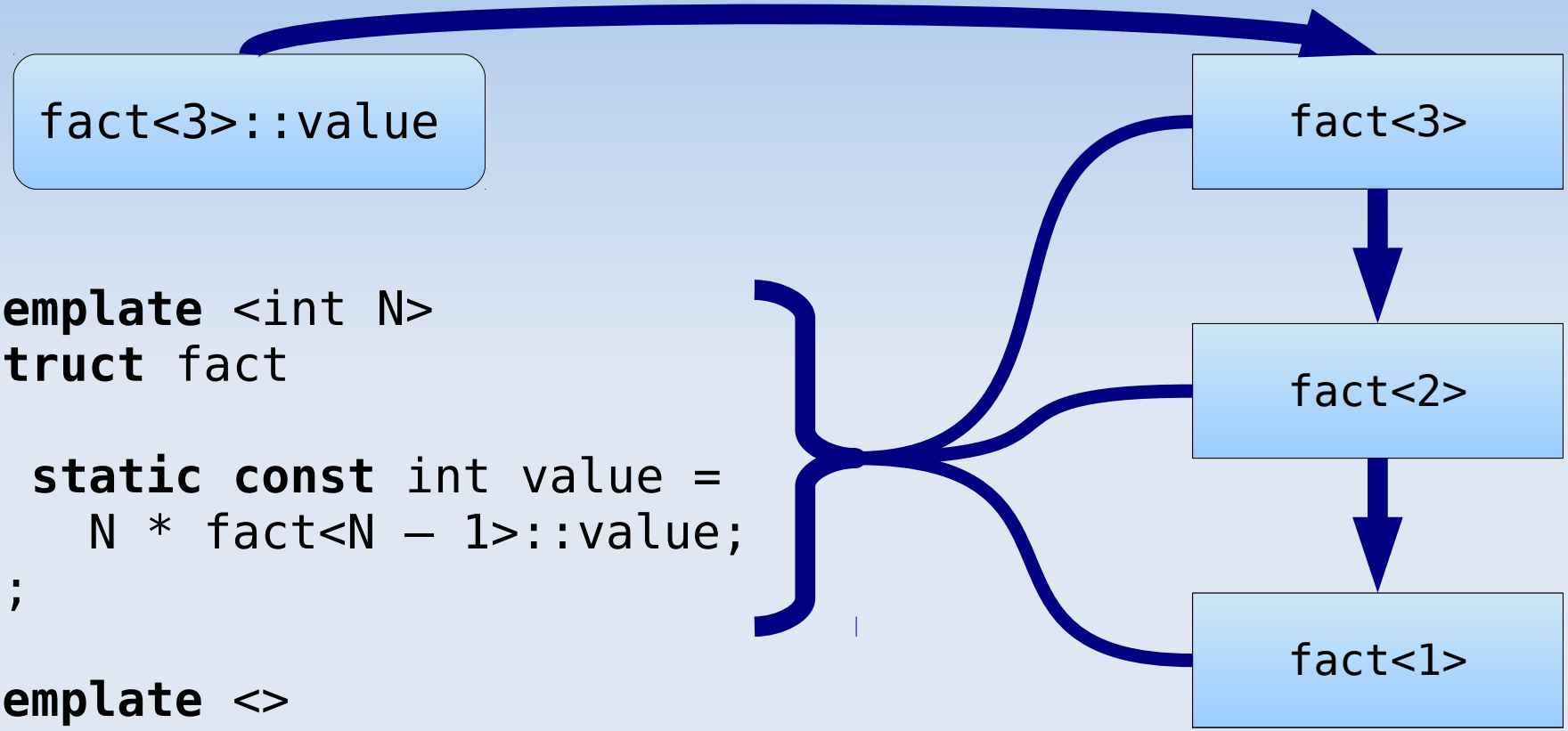


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C++ template metaprogramming

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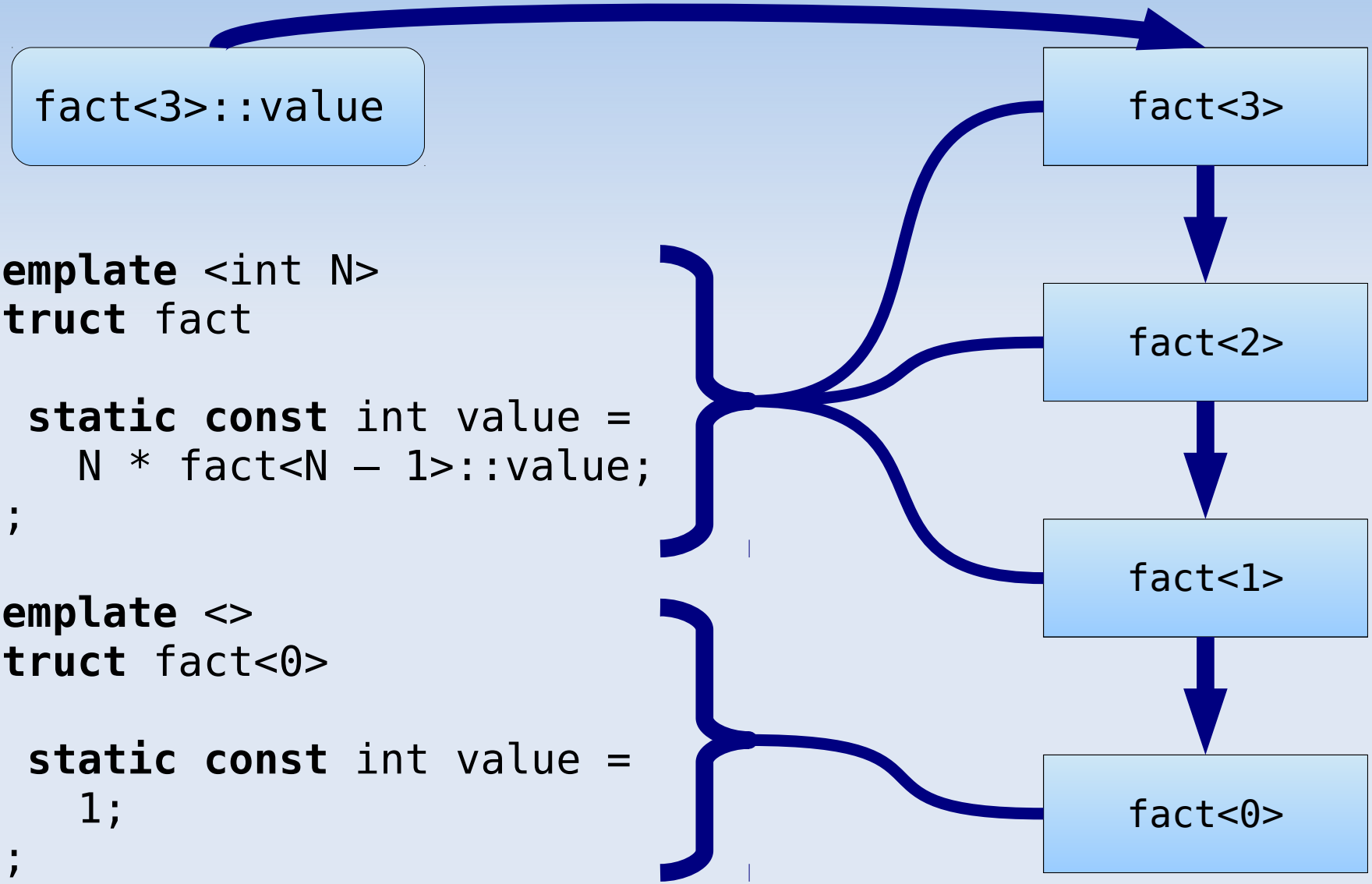

C++ template metafunction

Argument list

Name

Body

C++ template metafunction

```
template <class T>
struct add_const
{
  typedef const T type;
};
```

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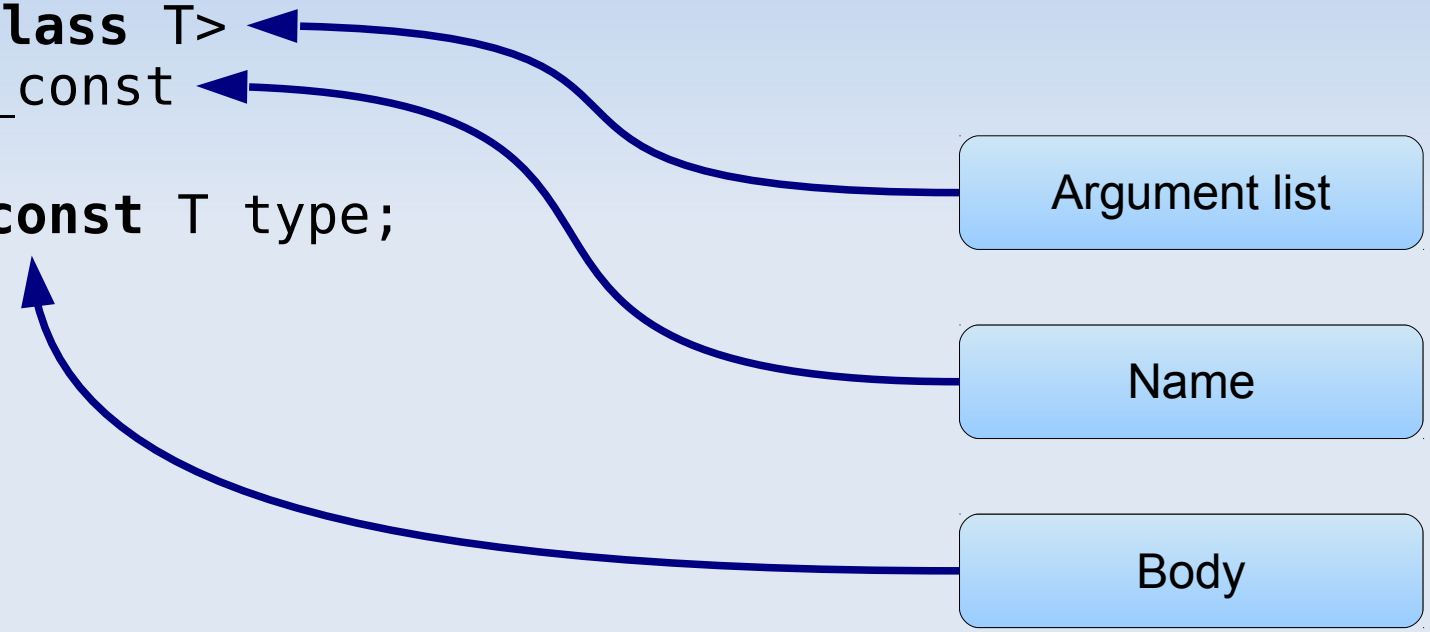

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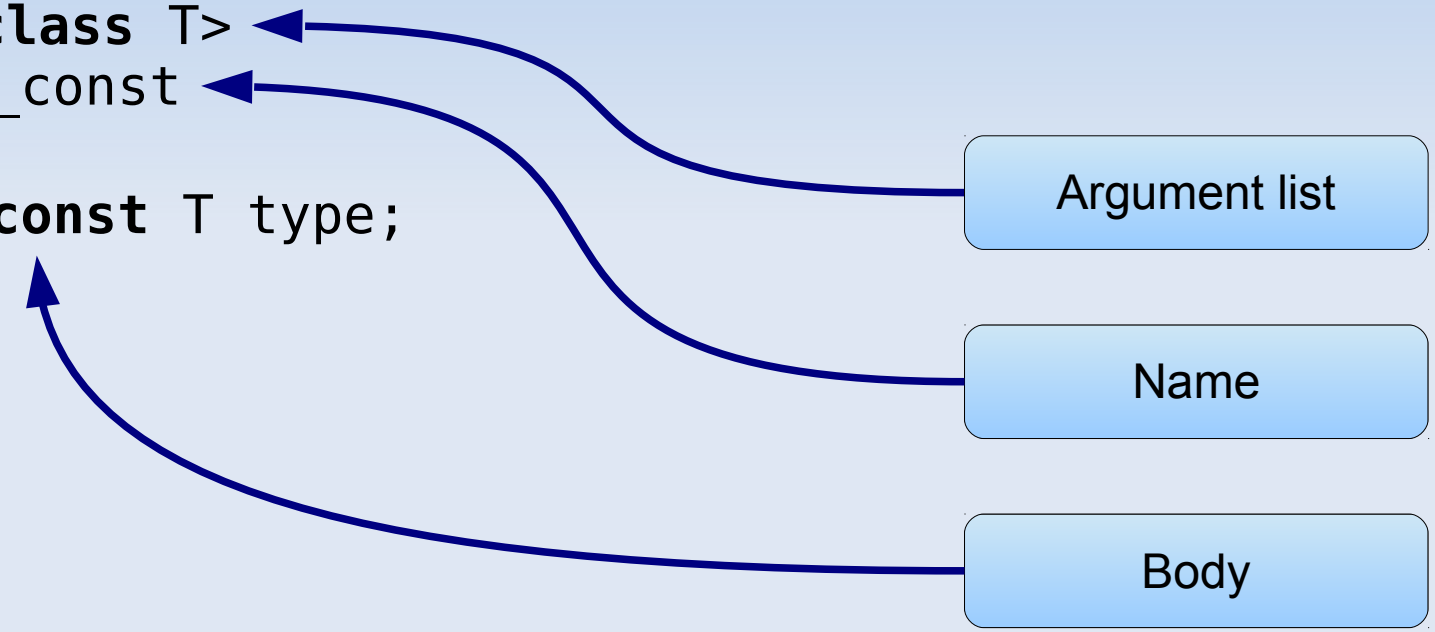


```
add_const<int>::type
```

C++ template metafunction

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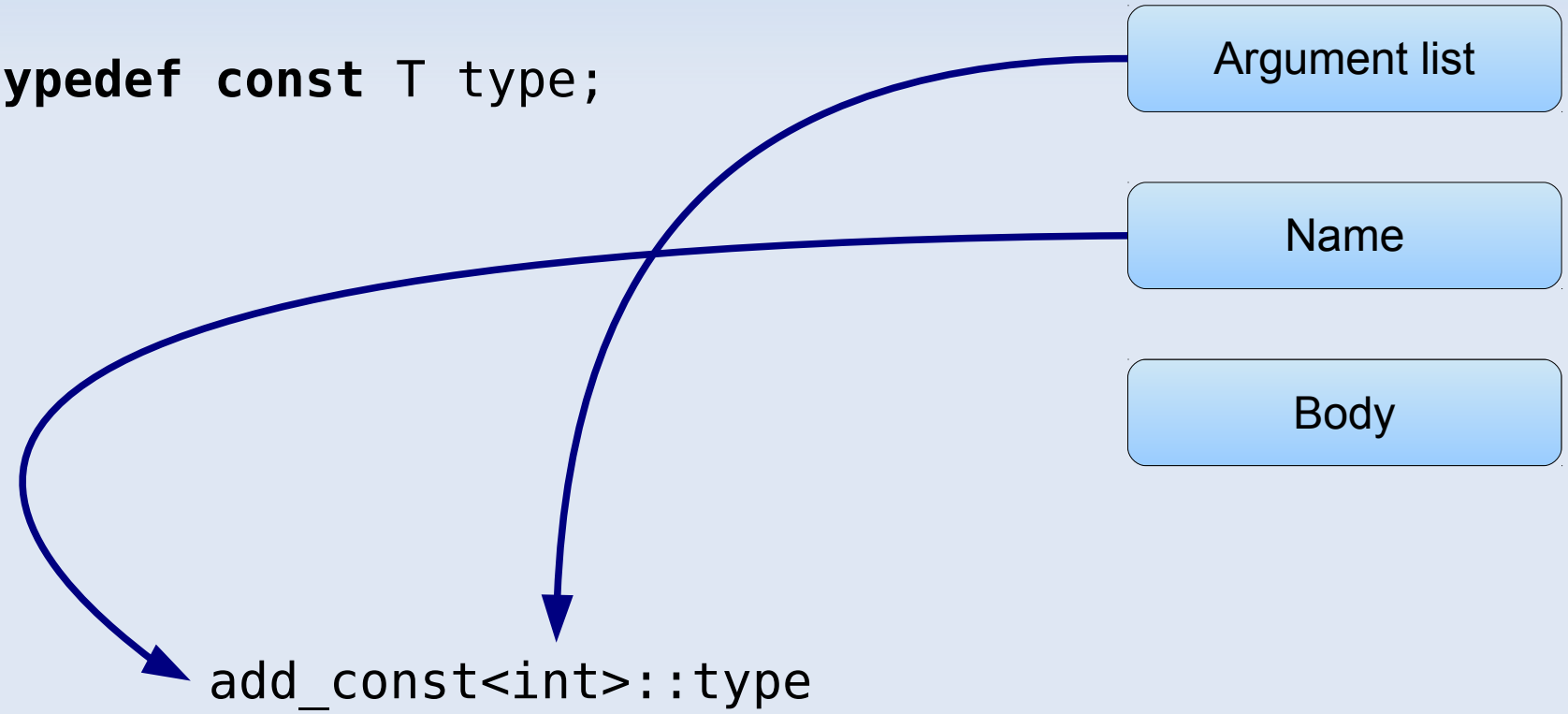
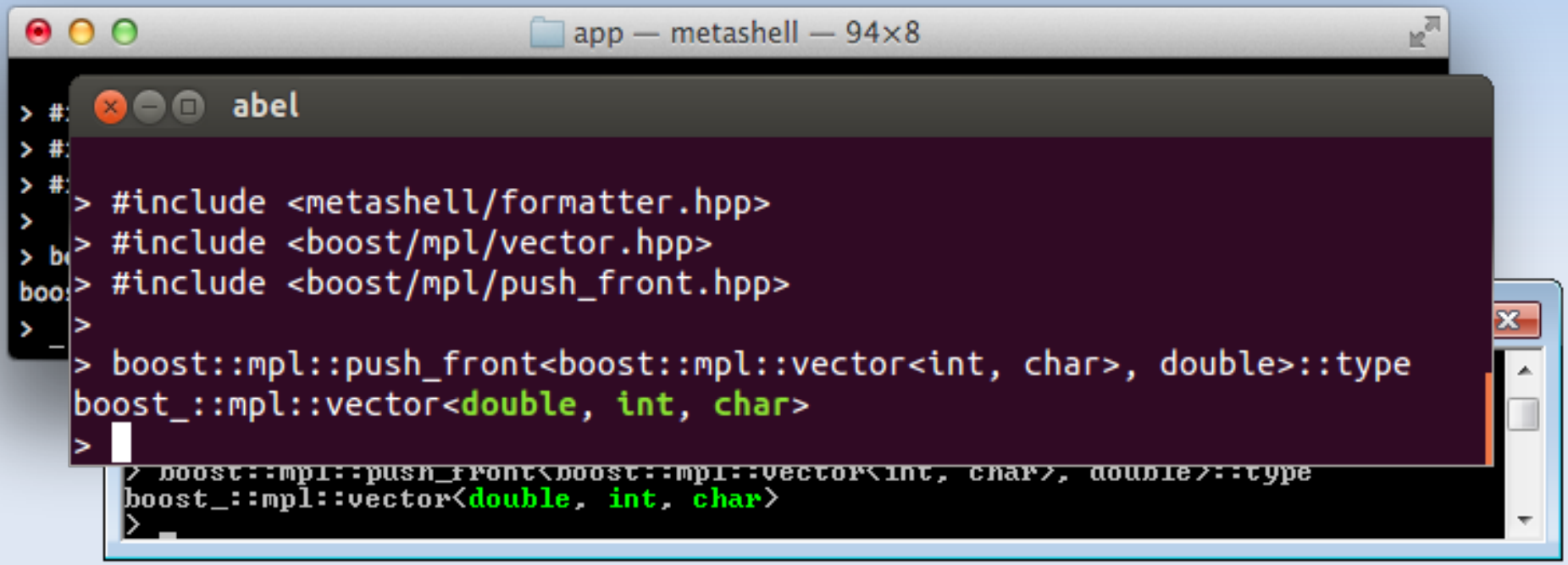


Metashell demo



Metashell: http://github.com/sabel83/metashell

Online demo: http://abel.web.elte.hu/shell

Technical break

Tool support

Run-time

Compile-time

Tool support

Run-time

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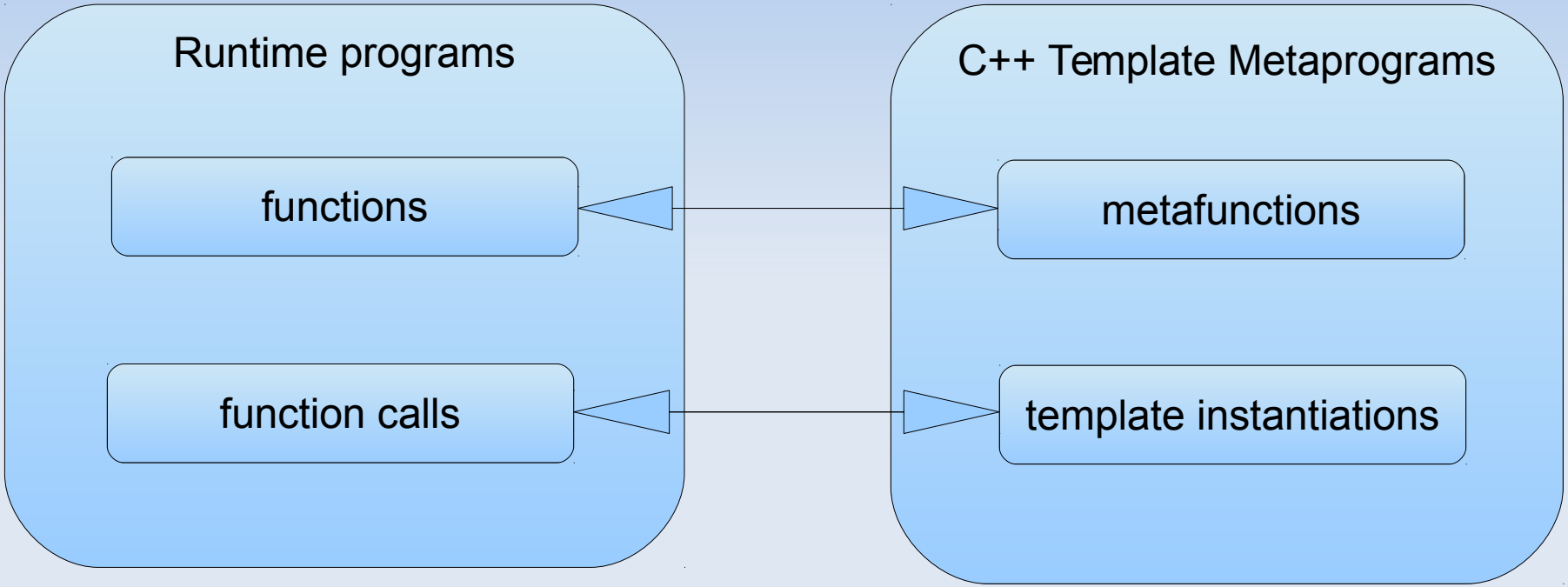
Runtime- vs. Metaprograms



Fibonacci

```
template <class N>
struct fib :
  eval_if<
    typename
    less<
      N, int_<2>
    >::type,
    int_<1>,
    fib_impl<N>
  >::type
{};
```

Fibonacci

fib<int_<4>>::type

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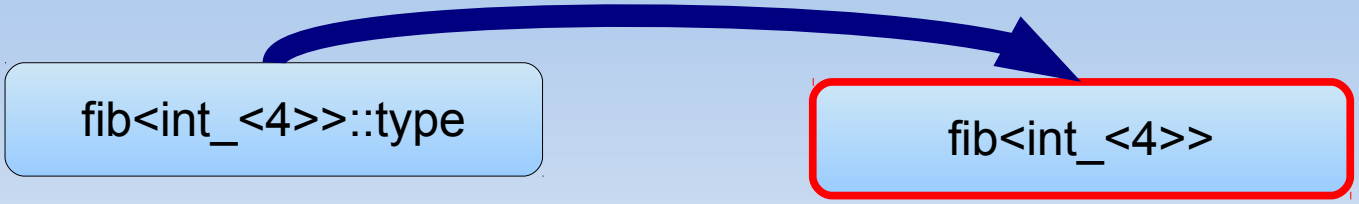
Fibonacci

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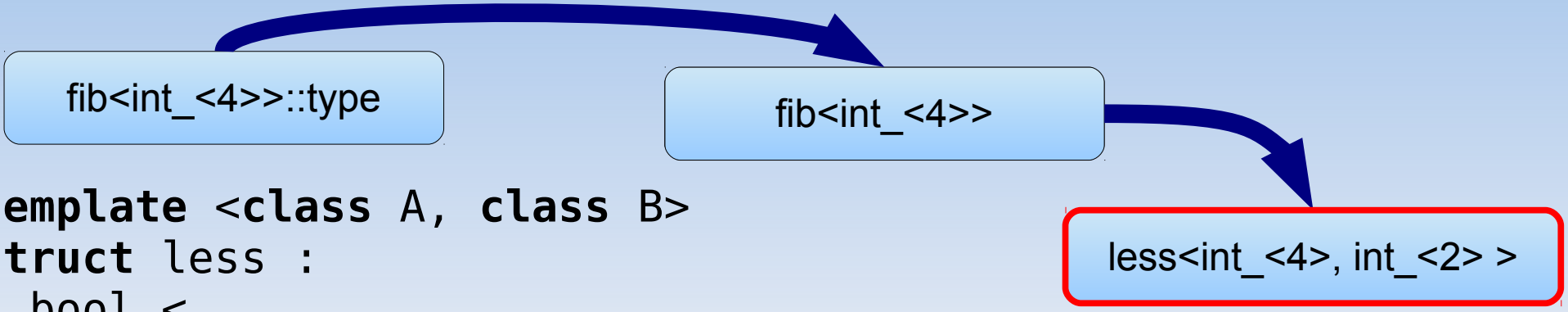
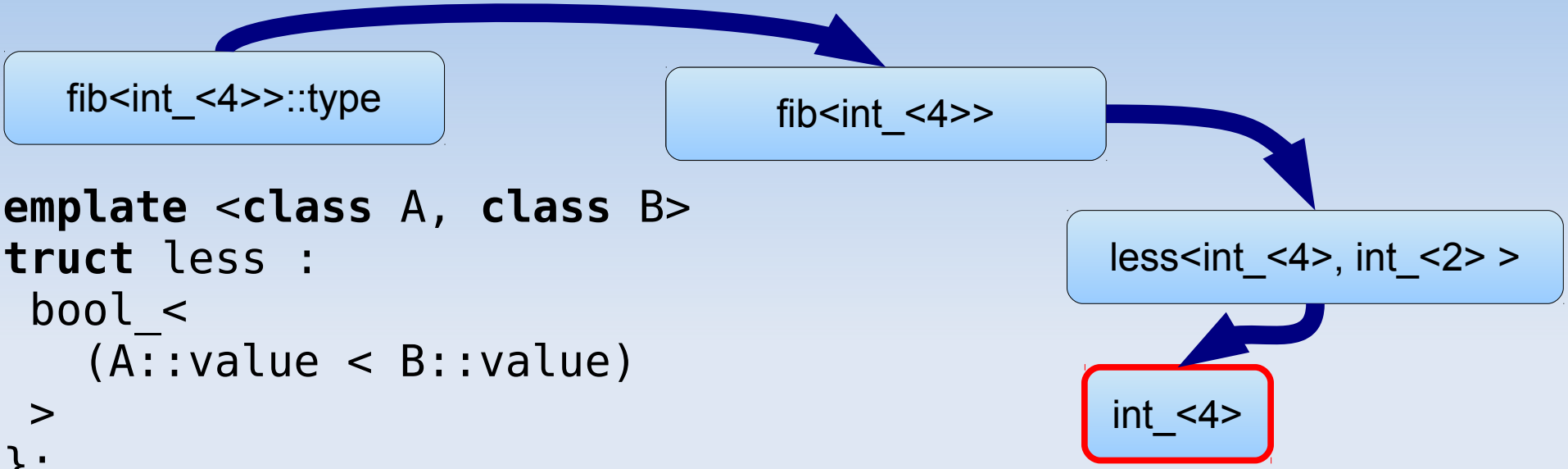



```
template <class A, class B>
struct less :
  bool_<
    (A::value < B::value)
  >
{};
```

Fibonacci

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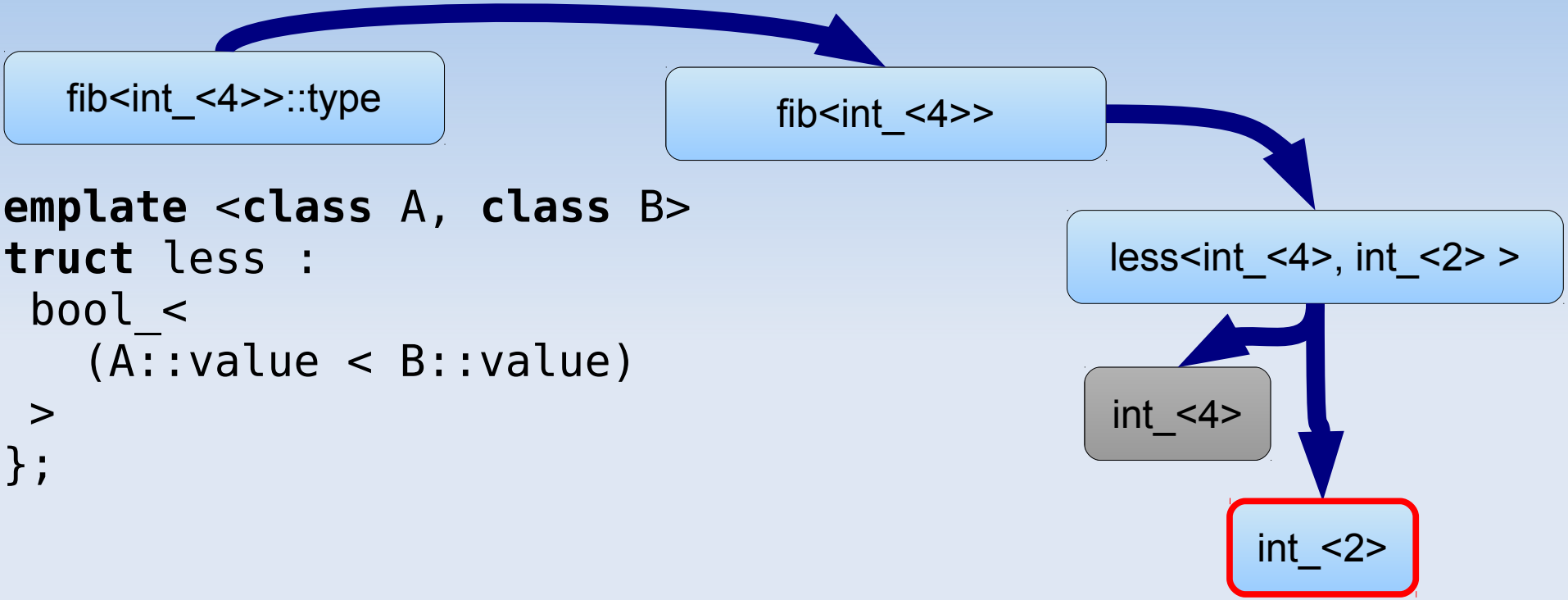
Fibonacci

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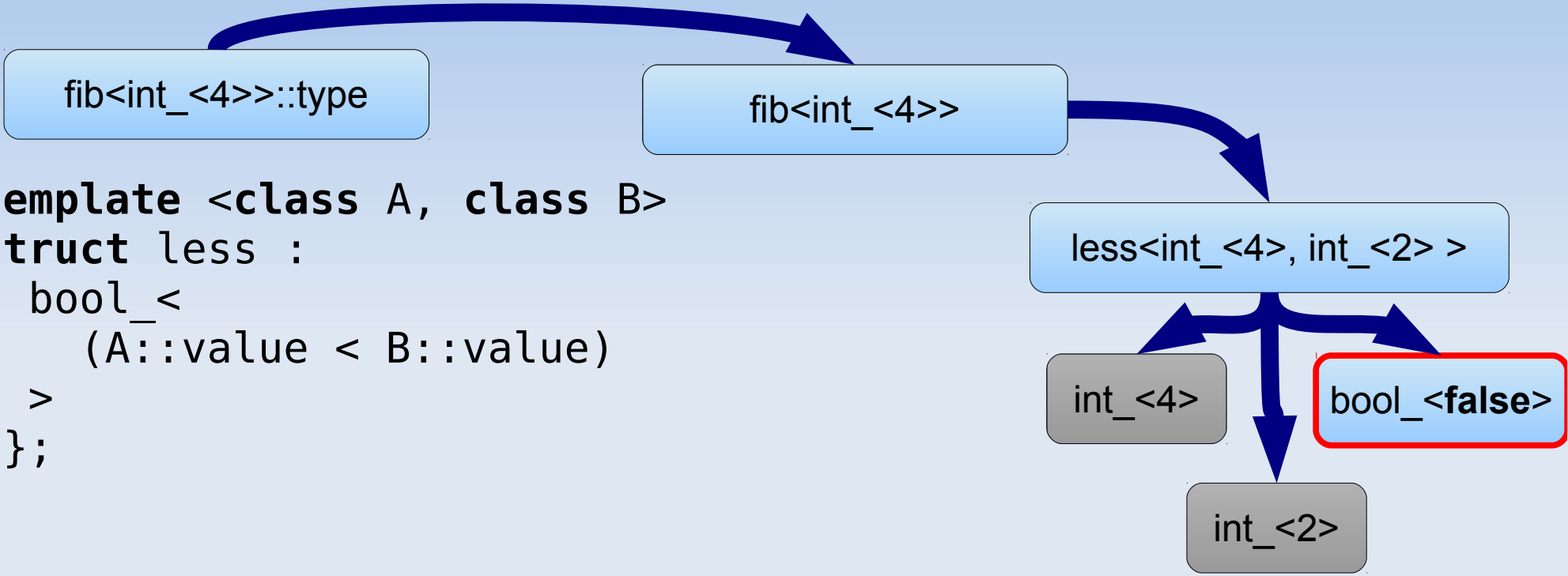
Fibonacci

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Fibonacci

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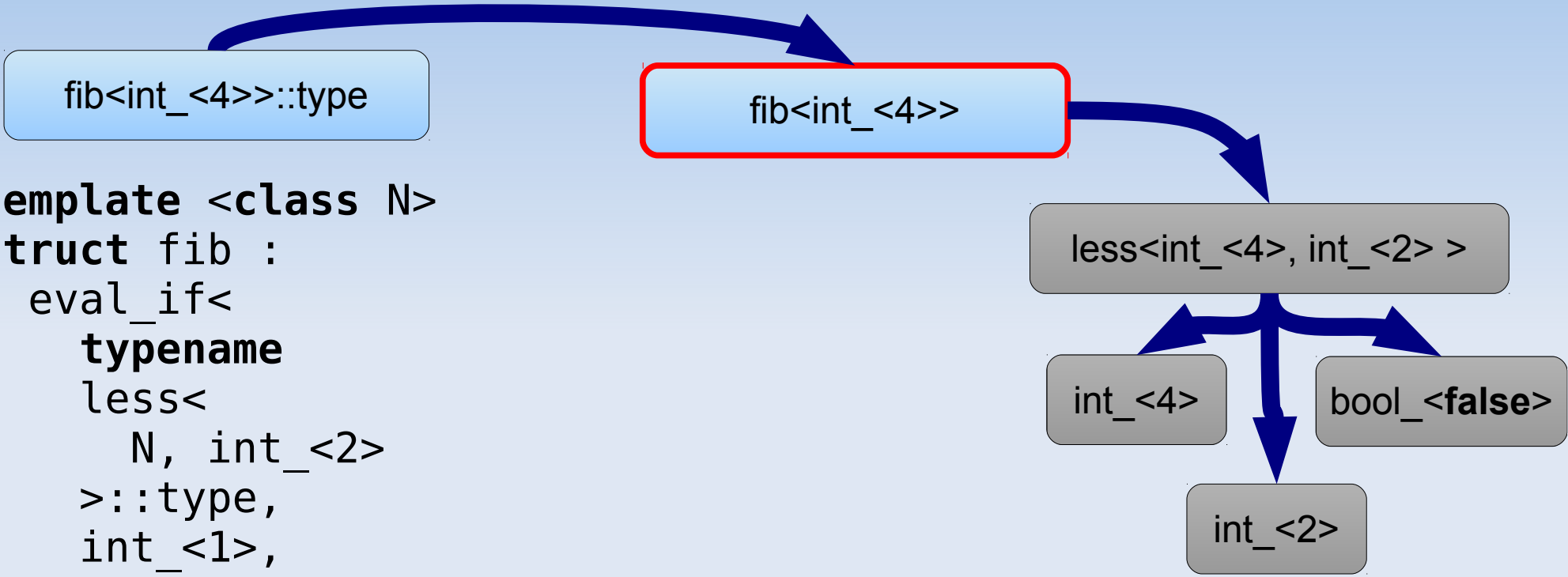
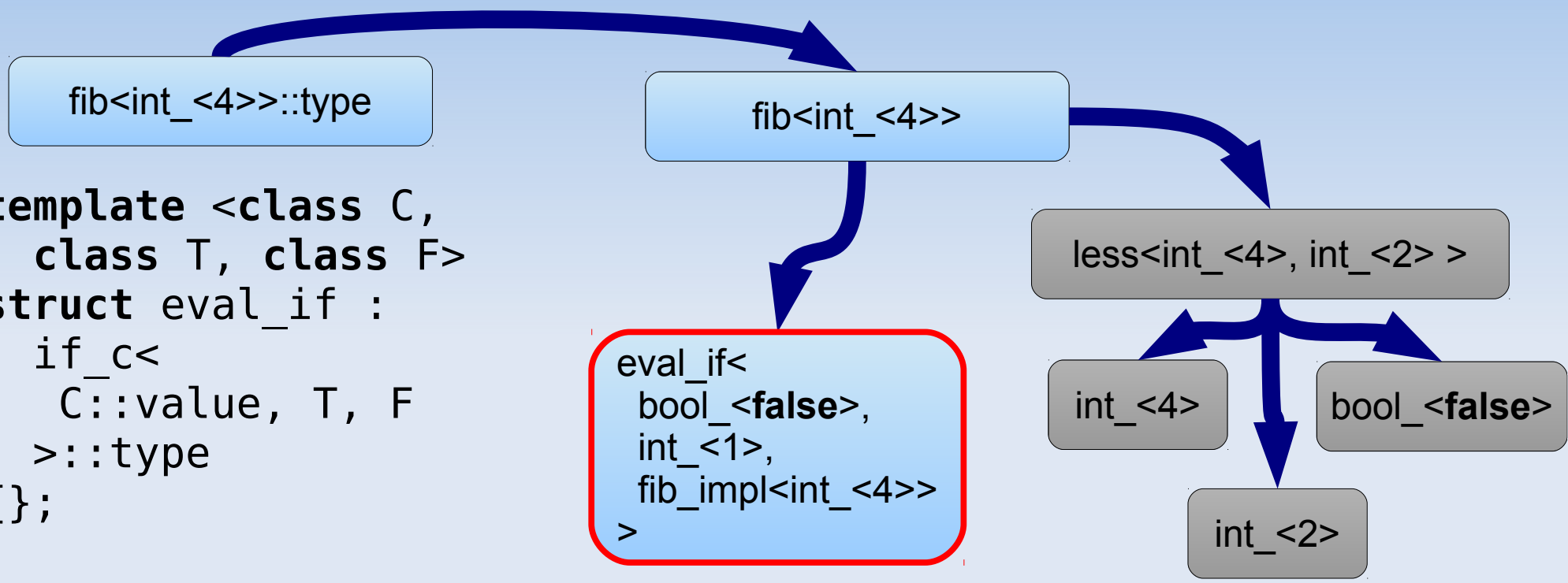


Fibonacci

```
template <class C,
  class T, class F>
struct eval_if :
  if_c<
   C::value, T, F
  >::type
{};
```



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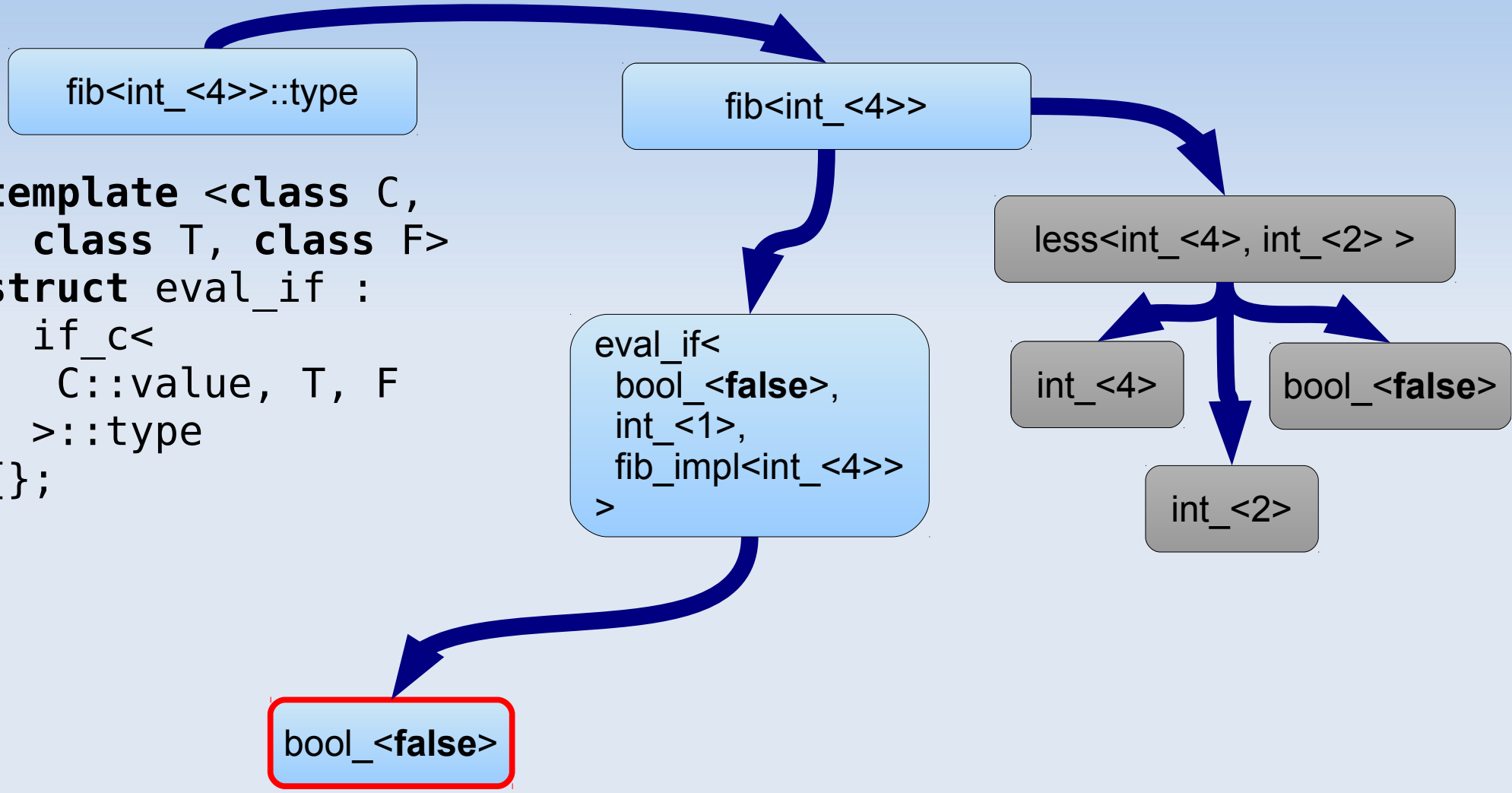

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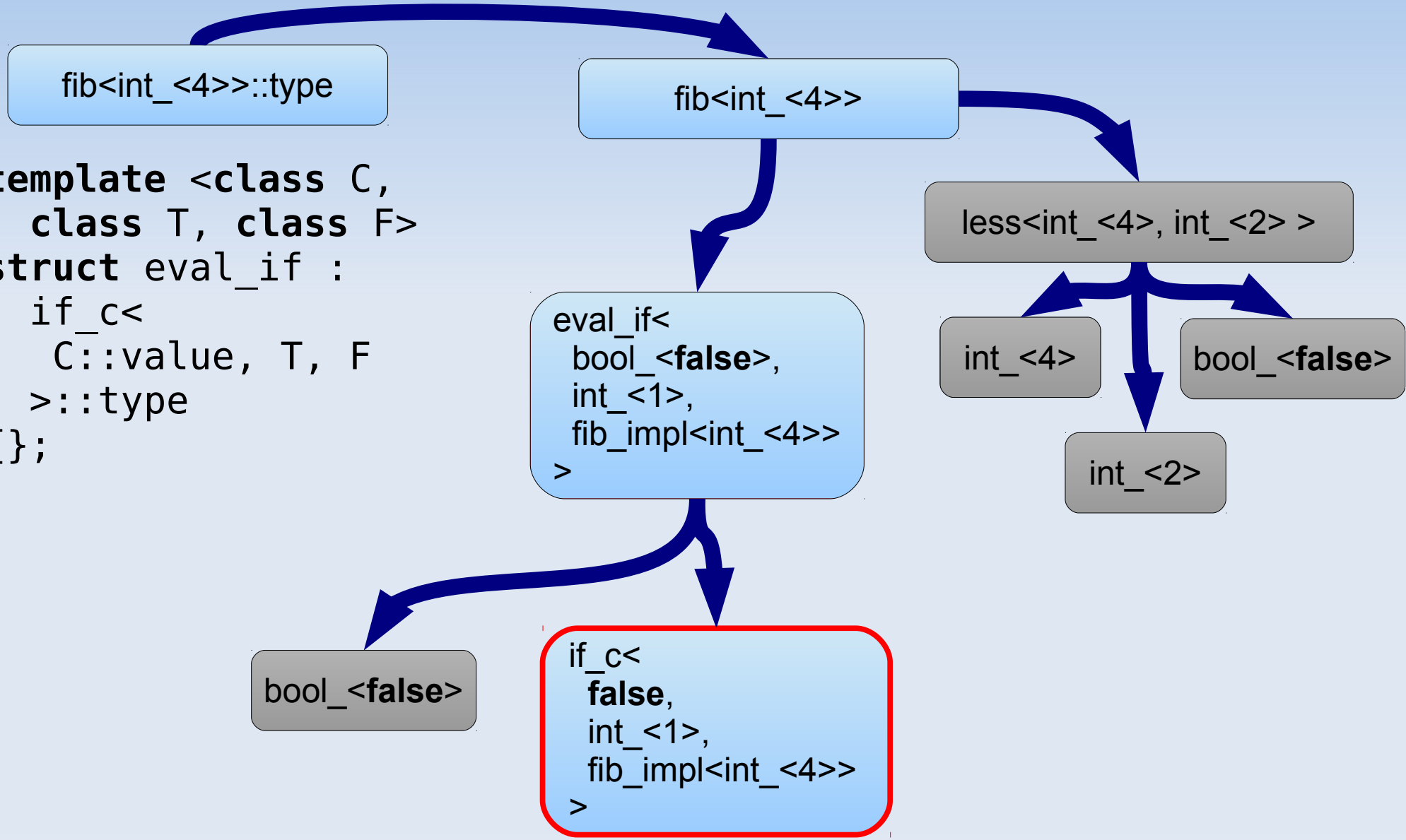

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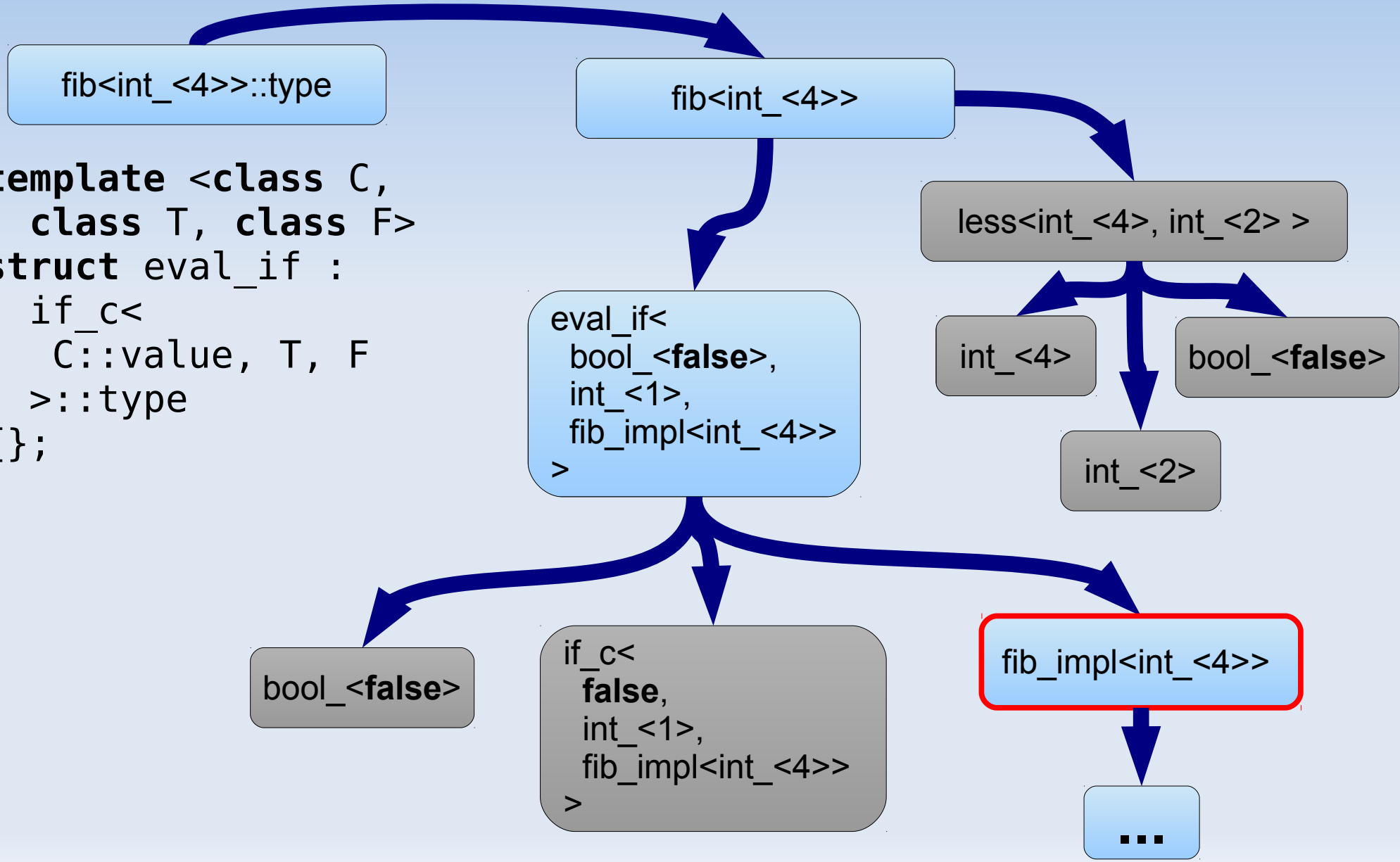
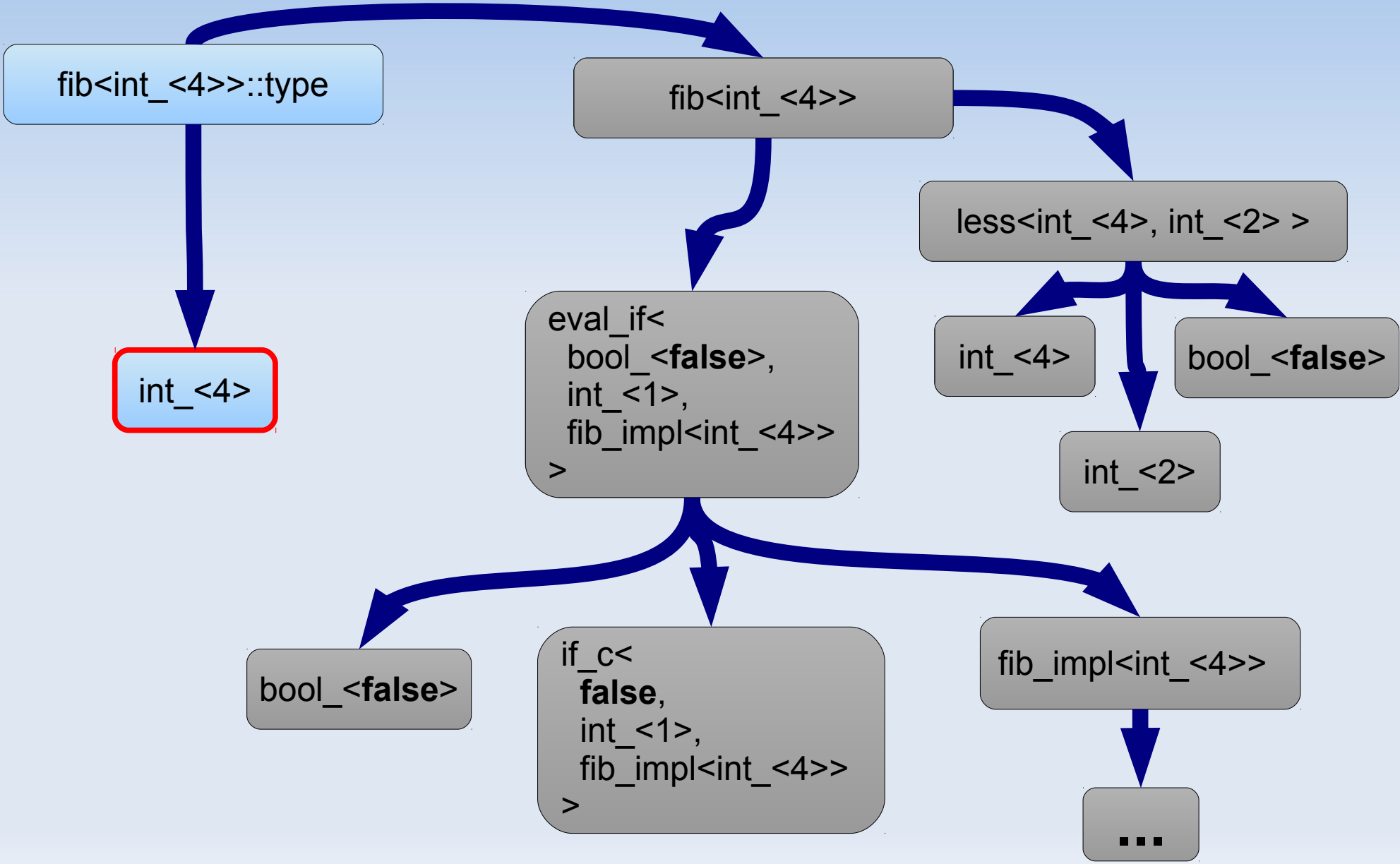
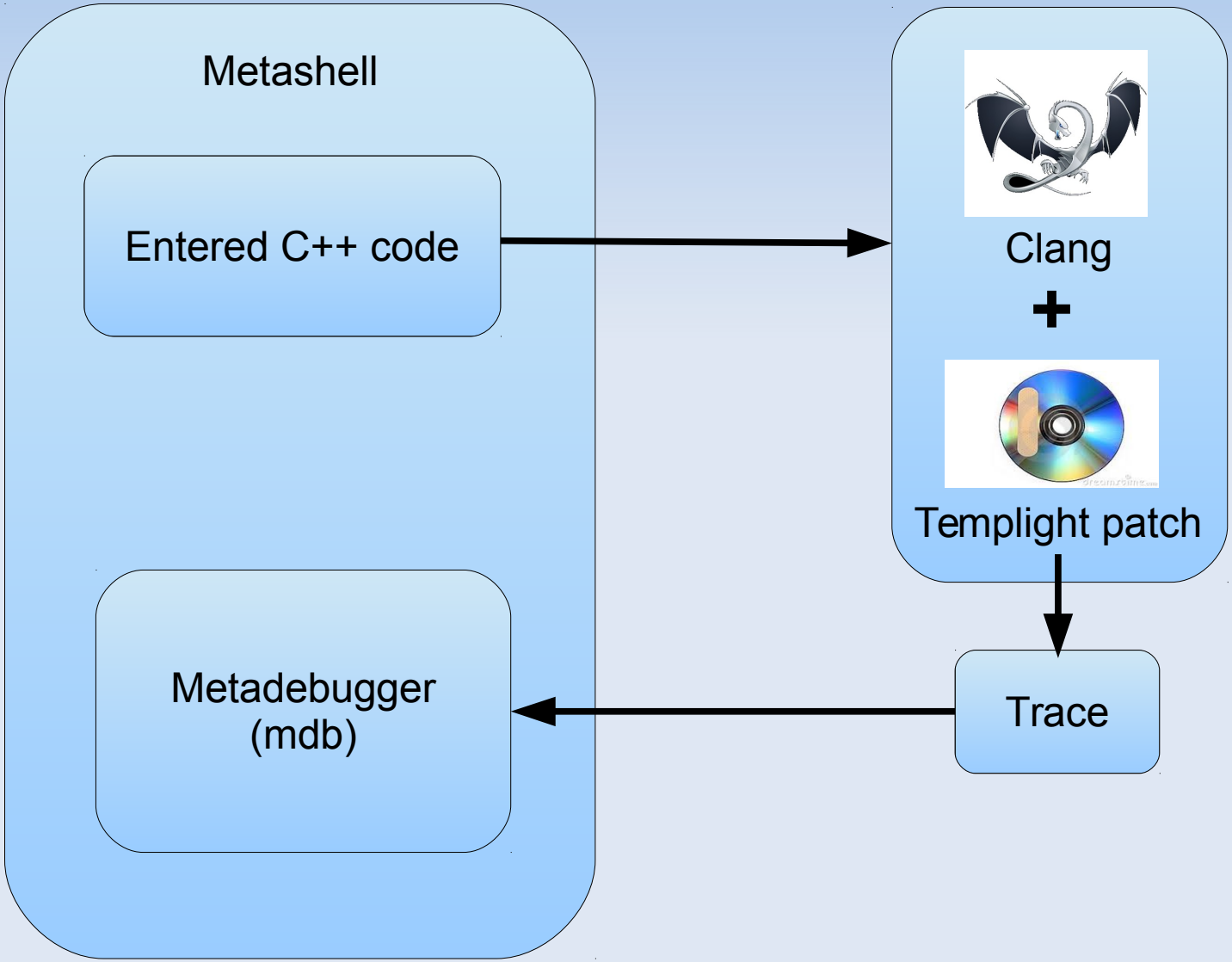


Fibonacci


fib<int_<4>>::type
int_<4>
fib<int_<4>>
eval_if<
bool_<**false**>,
int_<1>,
fib_impl<int_<4>>
>
less<int_<4>, int_<2> >
int_<4>
bool_<**false**>
int_<2>
bool_<**false**>
if_c<
false,
int_<1>,
fib_impl<int_<4>>
>
fib_impl<int_<4>>
...

Demo

Metadebugger



Demo

Tool support

Run-time

Compile-time

Tool support

Run-time

Compile-time

Future plans

- Display source location in the debugger
- Debug crashing metaprograms
- Interactive indentation of complex template instances
- Integrate Mikael Persson's Templight fork

Q & A

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http://github.com/r0mai

Metashell http://github.com/sabel83/metashell

Online demo http://abel.web.elte.hu/shell